

# **NASA's 3D Flight Computer for Space Applications**

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## **Abstract**

As part of NASA's New Millennium Program (NMP) to validate advanced technologies for future space flight mission in the new millennium, an Integrated Product Development Team (IPDT) for Microelectronics Systems has developed the 3D Flight Computer, as a general-purpose space flight computer. This computer uses the RAD6000-5L CPU technology from Lockheed Martin Federal systems, coupled with a total of 400 MB of local 3D-stacked DRAM memory for program storage and science data analysis, a local PCI bus interface and a VME system bus bridge, a high-bandwidth fiber-optic 1773 serial bus at 20 Mbps from Boeing, and 128 MB of non-volatile storage using Flash memory from TRW. These capabilities are packaged into four printed-circuit board 'slices' which are stacked in a 3D configuration using elastomeric 3D interconnects. The packaging approach was defined by Space Computer Corporation (SCC). Thus, with JPL as the space flight computer system integrator, the IPDT members for the flight computer development included: Lockheed Martin, Boeing, TRW, and SCC.

The 3D flight computer described above has a number of new technologies that were being developed for the first time for space applications. These include:

1. RAD6000-5L is a radiation hard fabrication process that enables the CPU to execute at 50 Mhz.
2. 3D DRAM stacks were being used to stack a total of 40 usable 16 Megabit DRAMs into a single 'sugar-cube' of silicon. The cubes actually stacked 48 die, of which 40 useful ones were selected. Each stack thus provided 80 MB of total storage with 80 MB of EDAC, thus providing a total of 320 MB of effective data storage. A total of 5 stacks were used on a single computer board slice.
3. 3D Flash memory stacks, 4-high were used to provide a total of 128 MB of non-volatile storage.
4. Advanced I/O module that provides both the PCI local bus and the PCI to VME bridge in a single computer slice. The same slice also provides the 1773 high-bandwidth (20 Mbps) serial fiber optic interface to the rest of the spacecraft system.
5. 3D Packaging technology enables the compact size and reduced volume of the complete stand-alone computer module.
6. An innovative approach to Design for Testability was also integrated into the design.

The 3D flight computer module shown in the figure below, can be used as a stand-alone computer module, or it can be mounted on a 6U VME card, for either integration and

testing, or to interface to other VME modules in the spacecraft integrated electronics module. The computer runs the VxWorks operating system with a C programming environment.

The computer module, as developed, was not delivered on schedule for validation on the New Millennium DS1 mission (which will launch in October 1998), as is currently available for validation in a future mission (or other validation opportunities).

The NMP 3D Flight Computer, even though it is not flying on the DS1 mission, represents a significant technology push towards highly integrated and miniaturized, and yet capable flight computer systems. Several aspects of this design have been further carried forward into the newly formed NASA Advanced Deep Space Systems Development Program (aka X2000). The Avionics that is being delivered as part of the X2000 program to five NASA projects also uses a modular, 3D-stacking approach to integrate not four modules, but, all of the on-board spacecraft avionics elements. In this regard, the NMP 3D flight computer for DS1 represents a significant milestone towards future highly miniaturized and integrated spacecraft avionics systems.

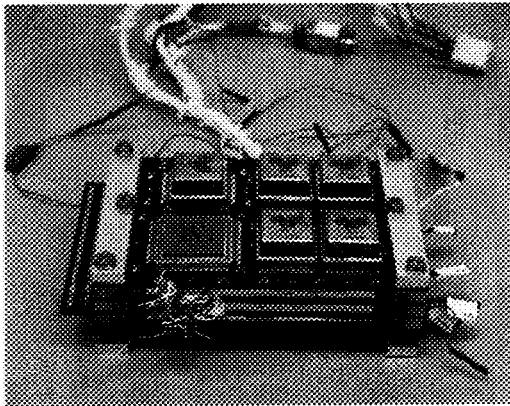


Figure 1 - 3D Flight Computer

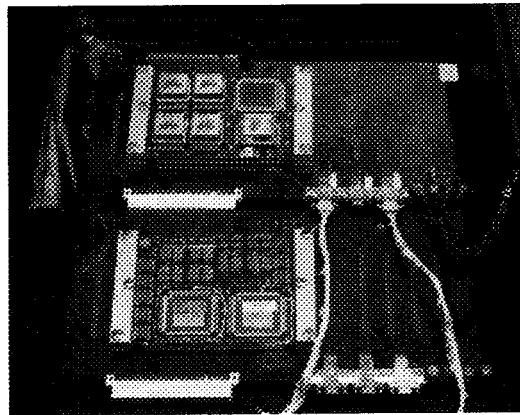


Figure 2 - Slices of 3D Flight Computer

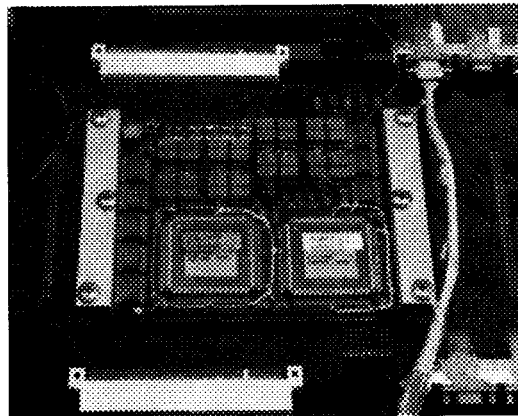


Figure 3 - Slice of 3D Flight Computer